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Experimental Results of SiC reinforced Al_2O_3 Matrix Ceramic Matrix Composites Validated with Finite Element Method

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***Abstract*: In this paper, SiC_p/Al_2O_3 composites were fabricated through directed metal oxidation process. Experimental results of these composites validated or compared with Finite Element Method (FEM). Finite Element has become one in all the foremost necessary tools offered to an engineer. The finite part methodology is employed to resolve advanced analysis issues.**

In this paper, Finite Element Method based ANSYS software is used to FEM model to determine mechanical properties of SiC reinforced Al_2O_3 matrix composite by changing volume fractions of SiC. The comparison of experimental results with Finite element analysis provides detailed information about the results of these comparisons. The FA was competent of predict the information for several scenario quite fine.

Keywords: CMCs, SiC, Al_2O_3, FEM, Mechanical Properties.

I. INTRODUCTION

Ceramic materials are suitable for low weight-density, high strength, temperature, hardness and wear resistance applications, but have relatively low fracture toughness [1]. This be capable of enhanced by addition a second phase that hold tall magnitudes of toughness, of which metallic reinforcement offers enormous possibility. Due to which affect the ductility, brittleness, microstructural features and mechanical properties of the materials [2].

S. Deepa Shri *et al* [3] studied the investigation is to predict the behavior of Hybrid Ferrocement slabs in bending. The equations are arrived and comparison between the theoretical and experimental values is done. Hillol Joardar *et al* [4] studied to estimate the results of assail particle on the microstructure associate degreed mechanical performance of associate degree metallic element alloy composite (LM6/SiC) created by stir casting. The experimental results unit finally compared with those obtained by finite half simulation. Hamid Sinaei *et al* [5] studied and validated FEA values with experimental values of reinforced concrete beam under 3-point bending. The values obtained from the FEA are aligned with the experimental values. Satya Prasad Paruchuru and Anju Jain [6] studied FEA fracture toughness values of CS specimen compared with experimental data.

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The purpose of this work is to comparison or validation of mechanical properties of SiC reinforced Al_2O_3 matrix composites fabricated as reported [7] with mechanical property values obtained from FEA simulation.

II. EXPERIMENTAL PROCEDURE

II.I. Fabrication of Al_2O_3-SiC Ceramic Matrix Composites

In this paper, the fabrication of SiC_p/Al_2O_3 composites with size measuring 70 × 70 × 20, in mm as explained in [7].

The FEM is used for studying some of the problems. To carry out current study, the FEM software package ANSYS was used. Different approaches to modeling the composite's internal geometry were looked at and a better understanding of the interface region between the two materials was gained. Comparison be completed with the experimental results on the SiC reinforced Al_2O_3 matrix composites with different volume fractions of SiC. A valid FEM model specimen was developed to study it mechanical properties. The FE model and the computational procedures were validated theoretically and experimentally. Experimentally tested results are compared with FEM results and validated the same.

III. RESULTS AND DISCUSSIONS

Directed metal oxidation processed SiC_p/Al_2O_3 composites mechanical properties reported in [7] are compared with mathematical models as explained below

III.I. Flexural Strength of Al_2O_3-SiC Ceramic Matrix Composites

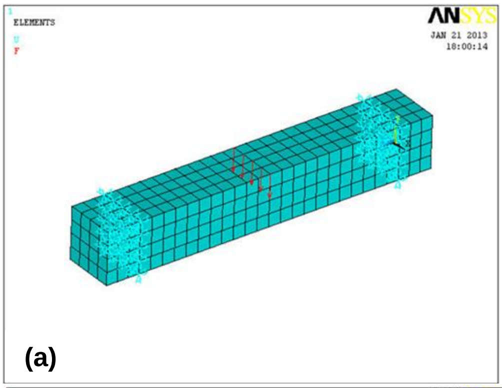
The models were based on the experiments of the three point bending tests done as per ASTM C1161-94 [8], where composite bars of 8 mm × 8 mm × 50 mm were used. To conduct a 3 point bending test, a FE model has been prepared by using ANSYS software as shown in Fig. 1 (a). The values of Young's modulus and Poison's ratio were taken from experimental results. The nodal solution of flexural strength by using ANSYS is shown in Fig. 1 (b), (c) and (d) for different volume fraction (Vf) of SiC in between 0.35 to 0.43.

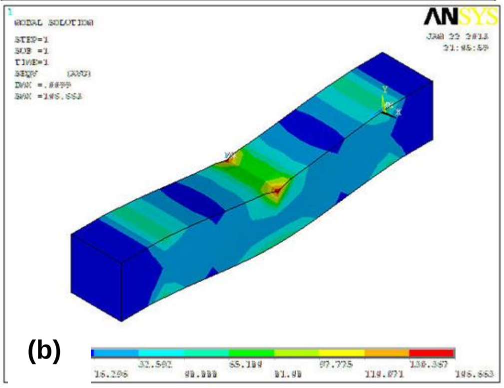
The flexural strength values reported [7] are compared with those obtained from FEM simulation in Table 1.

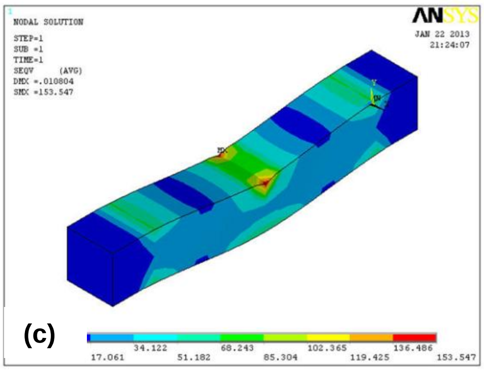
Table- I: Comparison of the experimental values of Flexural strengths of SiC_p/Al_2O_3 composites with those simulated by FEM

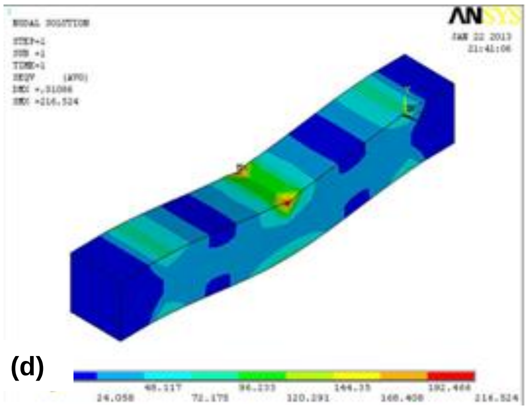
Label	SiC Volume Fraction	Flexural Strength, MPa		Deviation, (%)
		Experimental	Simulated by ANSYS	
B1	0.35	157.65	146.66	7.0
B2	0.40	161.00	153.55	4.6
B3	0.43	230.60	216.52	6.1

The same results are shown graphically in Fig. 1 (e).









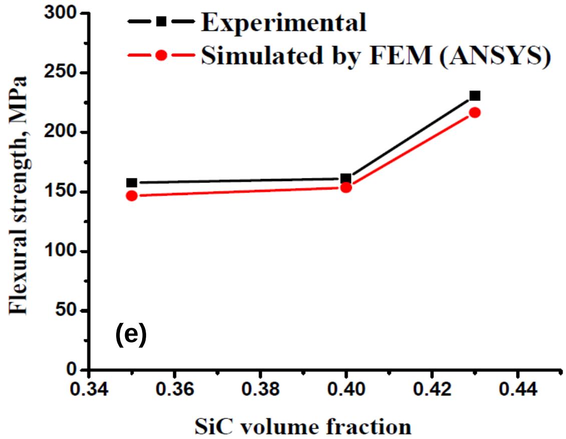


Fig.1: Flexural Strength of $SiCp/Al_2O_3$ ceramic matrix composite (a) 3-Point bend FEM model (b) Nodal Solution at Vf = 0.35 (c) Nodal Solution at Vf = 0.40 (d) Nodal Solution at Vf = 0.43 (e) Comparison of the experimental values with values simulated through FEM

The flexural strength values obtained from numerical analysis are comparable to those from the experimental results. This small deviation observed can be due to defects like porosity in the composites. The present investigations of mechanical behaviour of SiC_p/Al_2O_3 composites revealed that the flexural strength is greatly influenced by the particulate volume fraction in the matrix. While exactly matching experimental results was not a goal of this research, the comparison in Fig. 1 (e) does give a better understanding of the FEA models. In the models, the filler and matrix materials are considered to be perfectly bonded together with no voids or separation. In real-world experiments, this is nearly impossible to achieve. When a composite material is made, small air bubbles or porosity can get trapped between the two materials which lead to imperfect bonds.

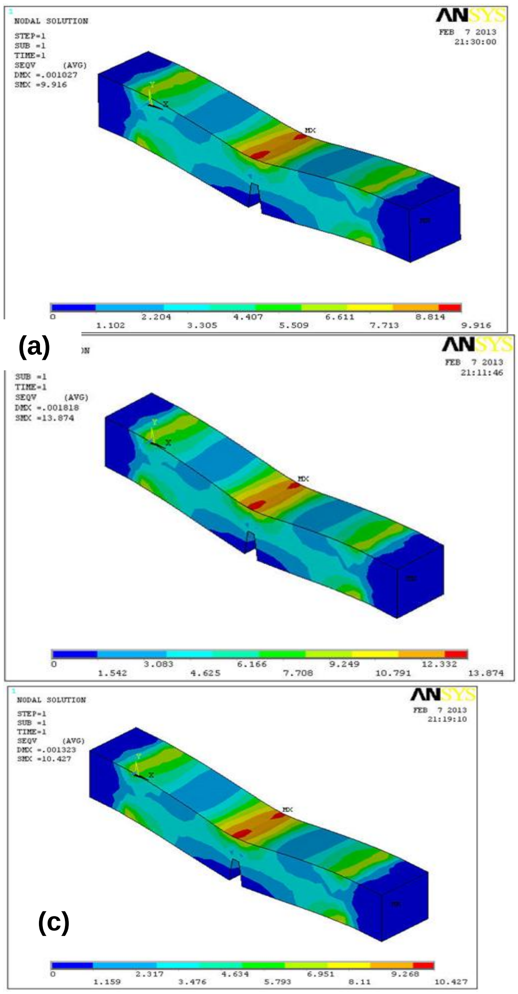
III.II. Fracture Toughness of Al_2O_3-SiC Ceramic Matrix Composites

The models were based on the experiments of three point bending single edge notch test which was done as per ASTM E 399-90 [9]. The nodal solution of fracture toughness by using ANSYS is shown in Fig 2 (a), (b) and (c) with varying SiC volume fraction in the vary from 0.35 to 0.43. In Table 2, we compare the values of fracture toughness computed using ANSYS with the experimental values reported in [7].

They are also compared graphically in Fig. 2 (d), from above figure results of FEA and of the experimental values are in relatively good agreement.

Table- II: Comparison of the experimental values of fracture toughness of SiC reinforced Al_2O_3 matrix composites with those simulated by FEM

Label	SiC Volume Fraction	Fracture toughness, $MPa.m^{1/2}$			Deviation (%)
		Experimental	Simulated by ANSYS		
			Σ	σ × 0.45 (a/w)	
B1	0.35	5.61	13.874	6.24	11.2
B2	0.40	4.64	10.427	4.69	1.1
B3	0.43	4.01	9.916	4.46	11.2



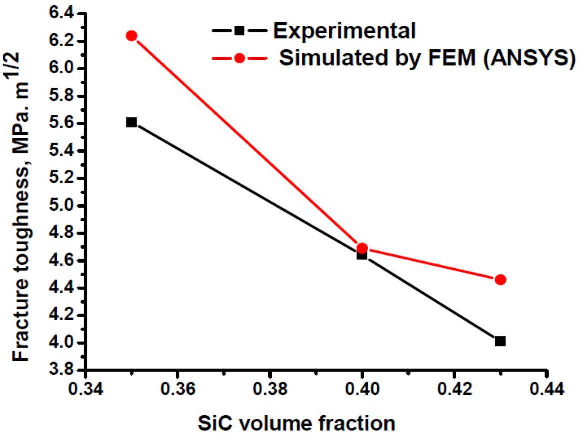


Fig.: 2. Fracture Toughness of SiC reinforced Al_2O_3 matrix composites (a) Nodal Solution at Vf = 0.35 (b) Nodal Solution at Vf = 0.40 (c) Nodal Solution at Vf = 0.43 (d) Comparison of the experimental values with values simulated through FEM

III.III. Compressive Strength of Al_2O_3-SiC Ceramic Ma[illegible]mposites

The models were based on experiments of uniaxial test done as per D3410M-95 [10], where composite bars 8 mm length, 8 mm width and 12 mm height were used. FE model designed using ANSYS software for compressive strength as discussed above. The nodal solution of compressive strength by using ANSYS is shown in Fig. 3 (a), (b) and (c) at different volume fractions of SiC in the range of 0.35 to 0.43. In Table 3, we compare the values of compressive strength computed using ANSYS with the experimental values reported in [7]. They are also compared graphically in Figure 3 (d).

The outcome of FEA and experimental values are in comparatively fine conformity. A small variation in FEA results and experimental results is due to bonding of reinforcement and matrix. In FEA modeling, the bonding between reinforcement and matrix is perfect because of no gaps; this will affect overall properties of the composite. In real-world testing, this perfect bonding is not possible.

Table-III: Comparison of the experimental values of Compressive Strength of SiC reinforced Al_2O_3 matrix composites with those simulated by FEM

Label	SiC Volume Fraction	Compressive Strength, MPa		Deviation (%)
		Experimental	Simulated by FEM (ANSYS)	
B1	0.35	668.00	638.15	4.46
B2	0.40	486.00	513.45	-5.64
B3	0.43	382.40	407.08	-6.45

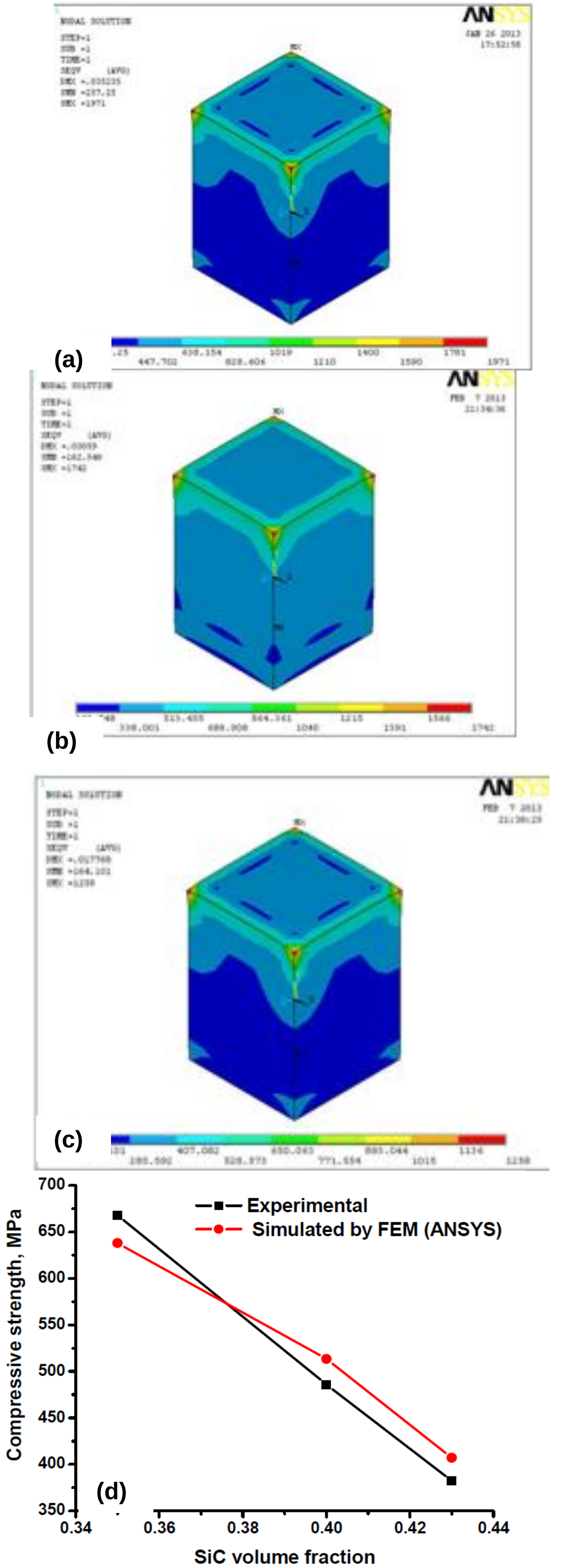


Fig. 3:. Compressive Strength of SiC reinforced Al_2O_3 matrix composites (a) Nodal Solution at Vf = 0.35 (b) Nodal Solution at Vf = 0.40 (c) Nodal Solution at Vf = 0.43 (d) Comparison of the experimental values with values simulated through FEM.

IV. CONCLUSIONS

SiC reinforced Al_2O_3 matrix composites fabricated and its mechanical properties reported in [7], was compared with Finite Element Analysis model results obtain and reported in this paper. FEM analysis was done by using ANSYS software. FEM model results of mechanical properties were validated with experimental results reported in [7]. The experimental results and FEM results values are in relatively good agreement.

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